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AGRICULTURAL ADAPTATION TO CLIMATE CHANGE IN THE SAHEL

PROFILES OF AGRICULTURAL MANAGEMENT PRACTICES

AUGUST 2014

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ARCC



African and Latin American
Resilience to Climate Change Project

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Cover Photo: Permeable rock dam, Burkina Faso. Credit: B.M. Simpson

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AFRICAN AND LATIN AMERICAN RESILIENCE TO CLIMATE CHANGE (ARCC)

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ACRONYMS AND ABBREVIATIONS

ACN	<i>Aménagement en courbes de niveau system</i>
AF	agroforestry
ARCC	USAID African and Latin American Resilience to Climate Change
CA	conservation agriculture
CDE	Centre for Development and Environment
CIAT	International Center for Tropical Agriculture
CIRAD	<i>Centre de Coopération Internationale en Recherche Agronomique pour le Développement</i>
DIARPA	<i>Diagnostic Rapide Pré-Aménagement</i>
FOA	Food and Agriculture Organization of the United Nations
FMNR	Farmer Managed Natural Regeneration
GIZ	<i>Gesellschaft für Internationale Zusammenarbeit</i>
ICRISAT	International Crops Research Institute for the Semi-Arid-Tropics
IER	<i>Institut d'Economie Rurale</i>
IFAD	International Fund for Agricultural Development
ICRISAT	International Crops Research Institute for the Semi-Arid-Tropics
IPRODI	<i>Instituto Provincial de Discapacidad</i>
ISFM	Integrated Soil Fertility Management
NVS	natural vegetative strips
RAIN	Rainwater Harvesting Implementation Network
SICA	<i>la Sistema Intensivo de Cultivo Arrocero</i>
SRI	System of Rice Intensification; <i>le Système de Riziculture Intensive</i>
VS	Vallerani System
WOCAT	World Overview of Conservation Approaches and Technologies

ABOUT THIS SERIES

THE STUDIES ON CLIMATE CHANGE VULNERABILITY AND ADAPTATION IN WEST AFRICA

This document is part of a series of studies produced by the African and Latin American Resilience to Climate Change (ARCC) project that address adaptation to climate change in West Africa. Within the ARCC West Africa studies, this document is part of the subseries Agricultural Adaptation to Climate Change in the Sahel. ARCC has also developed a subseries on Climate Change and Water Resources in West Africa, Climate Change and Conflict in West Africa, and Climate Change in Mali.

THE SUBSERIES ON AGRICULTURAL ADAPTATION TO CLIMATE CHANGE IN THE SAHEL

Upon the request of the United States Agency for International Development (USAID), ARCC undertook the Sahel series of studies to increase understanding of the potential impacts of climate change on agricultural productivity in the Sahel and to identify means to support adaptation to these impacts. Other documents in the Agricultural Adaptation to Climate Change in the Sahel series include An Approach to Conducting Phenological Screening; An Approach to Evaluating the Performance of Agricultural Practices; A Review of 15 Crops Cultivated in the Sahel; Expected Impacts on Pests and Diseases Afflicting Selected Crops; and Expected Impacts on Pests and Diseases Afflicting Livestock.

I.0 INTRODUCTION

Upon the request of USAID, ARCC researched the options for evaluating farm level practices under different climate scenarios. The resulting document, *An Approach to Evaluating the Performance of Agricultural Practices under Climate Change in the Sahel*, describes considerations for selecting among the various approaches available for evaluation. It also proposes three basic components to any such evaluation: defining expected changes in climate; defining adaptation objectives and the practices to be assessed; and conducting the evaluation of the defined practices.

This document falls into the second of these components. It presents profiles of farm-level practices, technologies, and methods (globally referred to here as “practices”) to aid in their selection and evaluation. The practices profiled here were selected based on their use by farmers in the Sahel to manage the impact of climate on crop productivity. They are organized into four categories according to their intended function: moisture retention; supplemental water supply; soil fertility enhancement; and temperature and wind speed abatement.

Effective methods to address climate variability and change are important in all farming contexts. The practices described here have been developed to address the major constraints to productivity in the Sahel. These include low soil fertility, high temperatures, low rainfall, and dry spells. The projected changes in climate in the Sahel may increase the severity of these constraints. Moisture retention and supplemental water supply will become more important as temperatures rise. Improved moisture management and decreased dependence on rainfall amounts and distribution will also rise in importance if rainfall declines or becomes more erratic and dry spells increase in frequency. Improved soil fertility will become critical as rising temperatures, drought, and more intense precipitation alter erosion rates, soil moisture, root growth, and plant phenology. Similarly, practices that mitigate the impact of higher temperatures and abate wind speed will become essential as climate change increases temperatures and alters rainfall amounts and patterns.

This document presents a total of 30 practices. Each case begins with an overview of the practice, followed by a technical description of the practice, a description of the climatic and topographic contexts for which the practice is suitable, limitations of the practice as noted in the literature, and key reference sources for the practice. Information used in the profiles was drawn exclusively from available research and technical literature. The documents selected for review focus primarily on the Sahel and West Africa, though in a few cases information regarding practices and their use in other semi-arid regions of the world was drawn upon as relevant and useful. The document concludes with a list of more general documents, less specific to particular practices, which were drawn upon in developing these profiles.

This paper constitutes one element of the ARCC effort to develop and implement an approach to understand the potential impacts of climate change on crop productivity in the Sahel, and identify means to support farmer adaptation to these expected changes. It may also be used as a standalone reference document of the farm-level practices, technologies, and methods crop farmers use to manage the impact of climate in the Sahel.

As is the case with any manual based on a review of literature, this study provides the foundation for many possible avenues of future research. Fieldwork could produce more precise descriptions of these practices, or could the compare the relative merits of the practices presented. The ARCC document *Climate Change In Mali: Organizational Survey and Focus Groups on Adaptive Practices* studied the promotion

and adoption of these and other adaptive practices in Mali. And the ARCC document *Agricultural Adaptive Practices Impact Modeling Assessment* evaluated the effectiveness of four of the water harvesting practices described here under current and projected future climatic conditions. These are just a few of the possible options for building on this work and developing a more comprehensive understanding of the options available to strengthen farmer adaptation to a changing climate in the Sahel.

2.0 MOISTURE CAPTURE AND RETENTION

2.1 TRAPEZOID BUNDS

Trapezoidal bunds are used to enclose areas up to 1 ha within which rainfall runoff is harvested. The name of the technique is derived from the layout of the structure that forms a trapezoid with a base bund connected to two side bunds or wingwalls that extend upslope. Crops are planted within the enclosed area. Overflow discharges around the tips of the wingwalls.

The general layout, consisting of a base bund connected to wingwalls is a common traditional water harvesting technique across Africa. The concept is similar in concept to the semi-circular bund technique (see following profile), though larger in scale. The simplicity of design and construction, minimum maintenance required and size of the enclosed planting area are the main advantages of this technique.

Each trapezoidal bund unit consists of a base bund connected to two wingwalls that extend upslope at an angle of 135 degrees. The size of the enclosed area depends on the slope and can vary from 0.1 to 1 ha. Trapezoidal bunds may be constructed as single units, or in sets. When built in a set, the bunds are arranged in a staggered configuration with units in the downslope tier capturing overflow from the bunds above. A common distance between the tips of adjacent bunds within one row is 20 m with 30 m spacing between the tips of the lower row and the base bunds of the upper row. The planner is of course free to select other layouts to best fit into the physical conditions of the site. It is not recommended to build more than two rows of trapezoidal bunds since those in a third or fourth row receive significantly less runoff.

Technical details

1. Length of base bund: around 40 m
2. Angle between base and side bunds: 135°
3. Minimum bund height (at tips): 0.20m
4. Maximum bund height: 0.60m

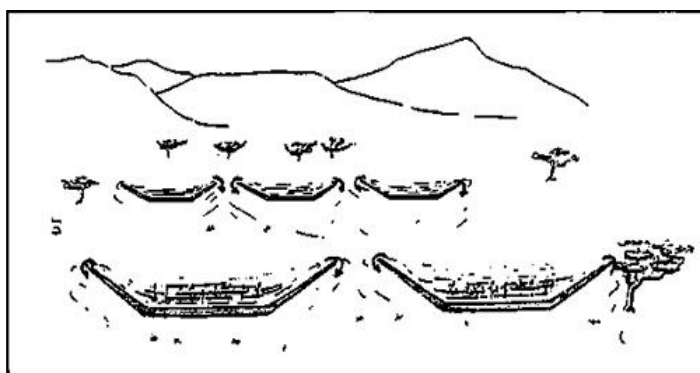
Suitability

Rainfall: 250 mm - 500 mm; arid to semi-arid areas.

Soils: agricultural soils with good construction properties, i.e. significant (non-cracking) clay content.

Slopes: from 0.25% - 1.5%, but most suitable below 0.5%.

FIGURE 1. A TRAPEZOID BUND



This method is used in the Turkana district of Kenya to trap rainwater.

Source: FAO

Topography: area within bunds should be even

Limitations: This technique is limited to low ground slopes. Construction of trapezoidal bunds on slopes steeper than 1.5% is technically feasible, but involves prohibitively large quantities of earthwork.

Sources

Critchley, W., and Siegert, K., with Chapman, C. (1991). "A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production." Food and Agriculture Organization: Rome.

Hatibu, N., & Mahoo, H. (1999). Rainwater harvesting technologies for agricultural production: A case for Dodoma, Tanzania. *Conservation tillage with animal traction*, 161.

2.2 SEMI-CIRCULAR BUNDS

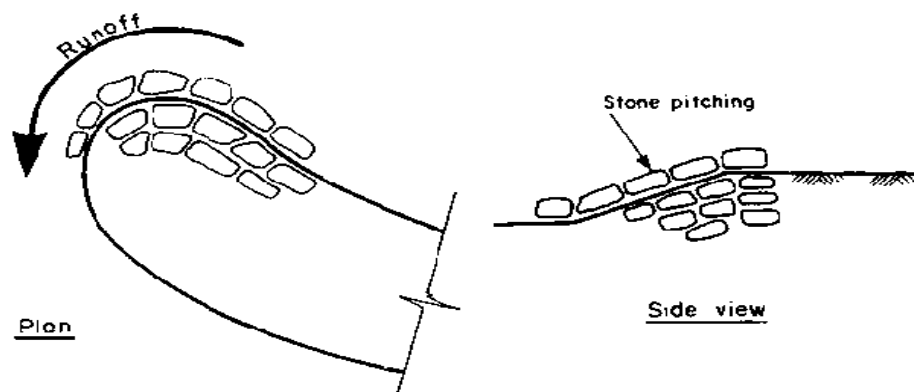
As the name implies semi-circular bunds are earth embankments shaped in a semi-circle with the tips of the bunds facing uphill and aligned on the contour. Semi-circular bunds, of varying dimensions, are used mainly for establishing trees, rangeland rehabilitation, fodder production and, in some cases, for growing crops. Depending on the configuration of the chosen site (esp. catchment: cultivated area ratio), the technique may be deployed as a short slope or long slope catchment technique.

Semi-circular bunds, (“demi-lune” in Francophone West Africa), are recommended as a quick and easy method of tree establishment and rangeland improvement in semi-arid areas. Semi-circular bunds are more efficient in terms of impounded area to bund volume than other equivalent structures - such as trapezoidal bunds for example. Surprisingly, this technique has never been used traditionally.

Technical details

1. Semi-circular bunds could have radii between 6-20 meters. They are constructed in staggered lines with runoff producing catchments between structures.
2. *Catchment: Cultivated area (C:CA)* ratio must be between 3:1 to 5:1.
3. Different variations depending on slope

FIGURE 2. SEMI-CIRCULAR BUNDS WITH PROTECTIVE STONE LAYER



Source: Critchley & Siegert, with Chapman. (1991), FOA

TABLE I. SEMI-CIRCULAR BUNDS

Land slope	Radius (m)	Length of bund (m)	Impounded area per bund (m ²)	Bunds per ha
Up to 1%	6	19	57	73
Up to 2%	20	63	630	4
4%	10	31	160	16

Suitability

Rainfall: 200 - 750 mm: from arid to semi-arid areas.

Soils: all soils which are not too shallow or saline.

Slopes: below 2%, but with modified bund designs up to 5%.

Topography: Even topography required, especially for design.

Limitation: construction cannot easily be mechanized.

Sources

Critchley, W., and Siegert, K., with Chapman, C. (1991). "A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production." Food and Agriculture Organization: Rome.

Hatibu, N., & Mahoo, H. (1999). Rainwater harvesting technologies for agricultural production: A case for Dodoma, Tanzania. *Conservation tillage with animal traction*, 161.

2.3 CONTOUR STONE BUNDS

Contour stone bunds are used to slow down and filter runoff, thereby increasing infiltration and capturing sediment. The water and sediment harvested lead directly to improved crop performance. This technique is well suited to small-scale application on farmer's fields and, given an adequate supply of stones, can be implemented quickly and cheaply over large areas.

The use of bunds — or lines of stones — is a traditional practice in parts of Sahelian West Africa, notably in Burkina Faso.

Improved construction and alignment along the contour makes the technique considerably more effective. The great advantage of systems based on stone is that there is no need for spillways, where potentially damaging flows are concentrated. The filtering effect of the semi-permeable barrier provides a better spreading effect of runoff than earth bunds, which attempt to capture runoff.

Furthermore, stone bunds require much less maintenance, although periodic maintenance is required, especially to repair damage caused by roaming cattle.

The use of stone bunds for water harvesting (as opposed to stone bunding for hillside terracing) has evolved into various forms (see Figure 4, right). Across all its variants it has proved an effective technique, which is popular and quickly mastered by farmers.

Technical details

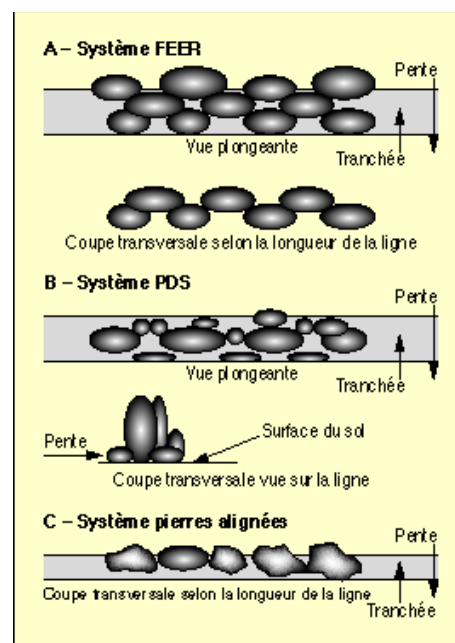
1. The spacing between bunds ranges normally between 15 and 30 m depending on the slope, amount of stone and labor available. Bund spacing of 20 meters for slopes of less than 1%, and 15 meters for slopes of 1-2%, are recommended. There is no need for diversion ditches or provision of spillways.
2. Although simple stone lines can be partially effective, depending on the technique used stones are placed in various configurations; it is important to incorporate a mixture of large and small stones. A recommended practice is to set the bunds into a shallow trench, of 5 - 10 cm depth, which helps to prevent undermining by runoff. A minimum bund height of 25 cm is recommended, with a base width of 35 - 40 cm.

FIGURE 3. CONTOUR STONE BUNDS: FIELD LAYOUT



Source: Crutchley & Reji, 1989

FIGURE 4. VARIANTS OF STONE BUNDS



Source: Somé, et al. (2000)

3. Design variation: Where not enough stone is readily available, stone lines can be used to form the framework of a system planting grass, or other material, immediately behind the stone lines. Over time, a “living barrier,” similar in effect to a stone bund, will form (see also Vegetative Strips). Alternatively, earth contour bunds can be constructed, with stone spillways set into them.

Suitability

Stone bunds for crop production can be used under the following conditions:

Rainfall: 200 mm - 750 mm; from arid to semi-arid areas.

Soils: agricultural soils.

Slopes: preferably below 2%.

Topography: need not be completely even.

Stone availability: must be good local supply of stone.

Limitation: Very labor intensive.

Sources

Critchley, W., and Siegert, K., with Chapman, C. (1991). “A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production.” Food and Agriculture Organization: Rome.

Nyssen, J., Poesen, J., Gebremichael, D., Vancampenhout, K., D’aes, M., Yihdego, G., ... & Deckers, J. (2007). Interdisciplinary on-site evaluation of stone bunds to control soil erosion on cropland in Northern Ethiopia. *Soil and Tillage Research*, 94(1): 51-163.

Somé, L., Kambou, F., Traore, S., and Ouedradogo, B. (2000). Techniques de conservation des eaux et des sols dans la moitié nord du Burkina Faso. *Science et Changement Planétaires/Sécheresse* 11(4): 267-74.

2.4 WATER SPREADING BUNDS

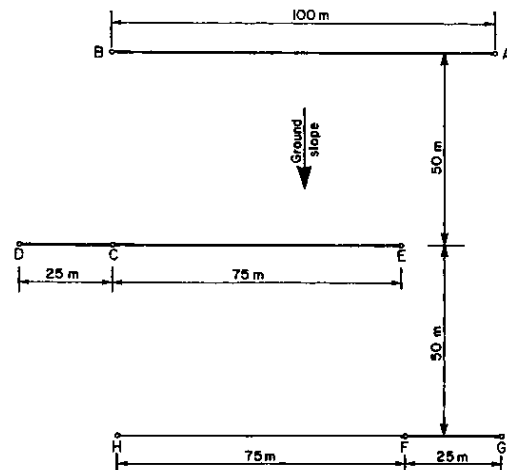
Water spreading bunds are often applied in situations where trapezoidal bunds are not suitable, usually where runoff discharge is high and would damage trapezoidal bunds, or where the crops to be grown are susceptible to the temporary waterlogging, which frequently occurs with trapezoidal bunds. The major characteristic of water spreading bunds is that, as their name implies, they are intended to spread water, and not to impound it.

The bunds are used to spread floodwater from a watercourse or to assist the even filling of floodplains. The bunds, typically constructed of earth, slow the flow of floodwater and spread it over the land to be cultivated, thus allowing it to infiltrate.

Technical Details

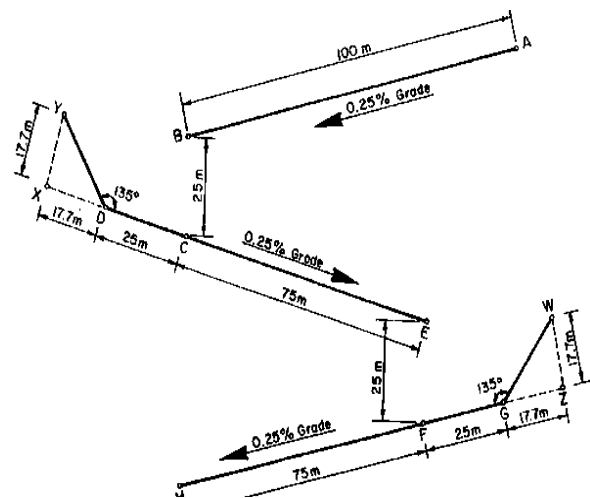
1. Where slopes are less than 0.5%, straight bunds are used across the slope to spread water. Both ends are left open to allow floodwater to pass around the bunds, which are sited at 50 meters apart. Bunds should overlap so that the overflow around one should be intercepted by that below it. The uniform cross section of the bunds is recommended to be 60 cm high, 4.1 meters base width, and a top width of 50 cm. This gives stable side slopes of 3:1. A maximum bund length of 100 meters is recommended.
2. In slopes range of 0.5% to 1.0% graded bunds can be used. Bunds, of constant cross-section, are graded along a ground slope of 0.25%. Each successive bund in the series downslope is graded from different ends. A short wingwall is constructed at 135° to the upper end of each bund to allow interception of the flow around the bund above. This has the effect of further checking the flow. The spacing between bunds depends on the slope of the land. Examples for different slopes are given in Figures 5 and 6. The bund cross section is the same as that recommended for contour bunds on lower slopes. The maximum length of a base bund is recommended to be 100 meters.

FIGURE 5. SETTING OUT LEVEL BUNDS: GROUND SLOPE LESS THAN .5%



Source: Critchley & Siegert, with Chapman. (1991)

FIGURE 6. SETTING OUT GRADED BUNDS FOR SLOPES MORE THAN .5%.



Source: Critchley & Siegert, with Chapman. (1991)

Suitability

Rainfall: 100 mm - 350 mm; normally hyper-arid/arid areas only.

Soils: alluvial fans or floodplains with deep fertile soils.

Slopes: most suitable for slopes of 1% or below.

Topography: even.

Limitation: Very site specific. The land must be sited close to a wadi or another watercourse, usually on a floodplain with alluvial soils and low slopes.

Source

Critchley, W., and Siegert, K., with Chapman, C. (1991). "A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production." Food and Agriculture Organization: Rome.

2.5 WATER SPREADING WEIRS

The first water-spreading weirs were introduced during the 1990s in Chad through Swiss cooperation, since then their use has spread to Burkina Faso and Niger. These weirs regulate floodwater in medium-sized watercourses and in wider degraded valley bottoms with a pronounced low-water channel. They are constructed with local materials and have a spillway in the middle, abutments on either side or long wing walls to spread the water over a large area.

Water spreading weirs span the entire width of a drainage area and are built of stonemasonry or concrete up to 50 cm above the surface of the surrounding land. They slow the flow of water in valleys and spread it over a wider area where it can infiltrate into the soil. In this way, they control river floodwater, thereby reducing erosion and water loss. At the same time, trapped sediments improve soil fertility and greater infiltration replenishes aquifers.

At times when floodwater flow is stronger, the water is channeled towards the sides and flows over the outer, lower wingwalls. When the floodwaters are at their heaviest, the water flows over even the higher walls. Downstream of the weir, water rejoins the established channel.

IMAGE 1. WATER-SPREADING WEIR IN THE SAHEL



Photo Credit: GIZ (2012)

Technical Details

1. Length of the weir: 50-100m
2. Length of the wingwall: 100-200m
3. Height of the weir: 1-4 m

Suitability

Annual Rainfall: 250-500mm

Landform: valley floors; drainages

Slope: flat to gentle, not suited for moderate or steep slopes

Soil depth: 50-120cm

Soil texture: fine, heavy (clay)

Ground water table: 5-50m

Soil water capacity: medium

Water spreading weirs are tolerant to climatic extremes such as increases in seasonal rainfall, heavy rainfall events, and floods.

Sources

GIZ. (2012). Good Practices in Soil and Water Conservation: A contribution to adaptation and farmers' resilience towards climate change in the Sahel.

Mekdaschi Studer, R., and Liniger, H. (2013) Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD): Rome.

2.6 NEGARIM MICROCATCHMENTS

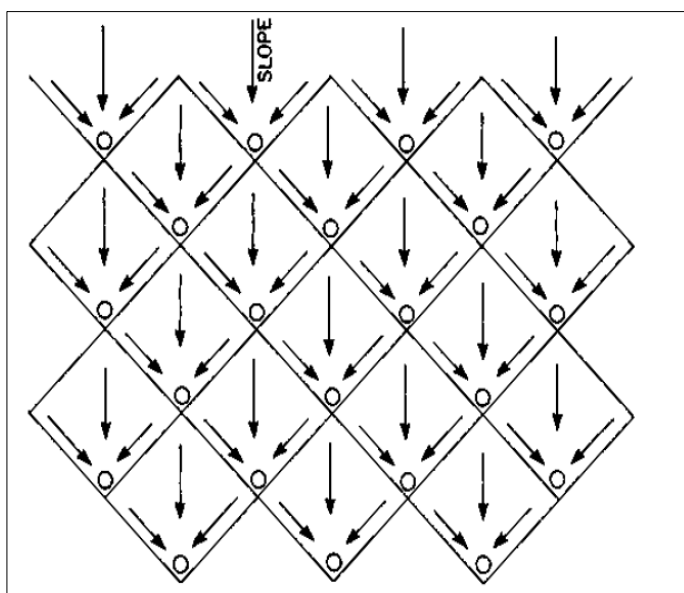
Negarim microcatchments are diamond-shaped basins surrounded by small earth bunds with an infiltration pit in the lowest corner of each. Runoff is collected from within the basin and stored in the infiltration pit. Microcatchments are mainly used for growing trees or bushes. This technique is appropriate for small-scale tree planting in any area that is moisture deficit. Besides harvesting water for the trees, it simultaneously conserves soil. Negarim microcatchments are neat and precise, and relatively easy to construct.

The word “Negarim” is derived from the Hebrew word for runoff - “Neger.” The reports identified citing use of these of microcatchments are from work carried out in Southern Tunisia, the technique, however, originated in the Negev desert of Israel. Variations of these microcatchments are found across the semi-arid and arid areas or North and Sub-Saharan Africa.

Technical details

1. Size of microcatchments (per unit) normally range between 10 m² and 100 m² depending on the species of tree to be planted but larger sizes are also feasible, particularly when more than one tree will be grown within one unit.
2. Each microcatchment consists of a catchment area and an infiltration pit. The shape of each unit is normally square, giving the appearance from above of a network of diamond shapes with infiltration pits in the lowest corners (Figure).
3. The top of the bund should be at least 25 cm wide and side slopes should be at least in the range of 1:1 in order to reduce soil erosion during rainstorms. Whenever possible, the bunds should be provided with a grass cover since this is the best protection against erosion.
4. A maximum depth of 40 cm for the infiltration pit should not be exceeded in order to avoid water losses through deep percolation and to reduce the workload for excavation.

**FIGURE 7. NEGARIM MICROCATCHMENTS:
FIELD LAYOUT**



Credit: Critchley & Siegert, with Chapman. FAO. (1991).

Suitability

Climate: arid and semi-arid areas.

Rainfall: can be as low as 150 mm per annum.

Soils: should be at least 1.5 m but preferably 2 m deep in order to ensure adequate root development and storage of the water harvested.

Slopes: from flat up to 5.0%.

Topography: need not be even - if uneven a block of microcatchments should be subdivided.

Limitations: The construction of Negarim microcatchments are well suited for hand construction, they cannot easily be mechanized. Once the trees are planted, it is not possible to operate and cultivate with machines between the tree lines.

TABLE 2. NEGARIM MICROCATCHMENTS

Size unit microcatchment (m ²)	Ground Slope			
	2%	3%	4%	5%
3x3	25	25	25	25
4x4	25	25	25	30
5x5	25	25	30	35
6x6	25	25	35	45
8x8	25	35	45	55
10x12	30	45	55	NR
12x12	35	50	NR	NR
15x15	45	NR	NR	NR

Key: NR = Not Recommended

Sources

Critchley, W. & Siegert, K., with Chapman, C. (1991). "A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production." Food and Agriculture Organization: Rome.

Renner, H. F., & Frasier, G. (1995). Microcatchment Water Harvesting for Agricultural Production. Part I: Physical and Technical Considerations. *Rangelands* 17(3): 72-78.

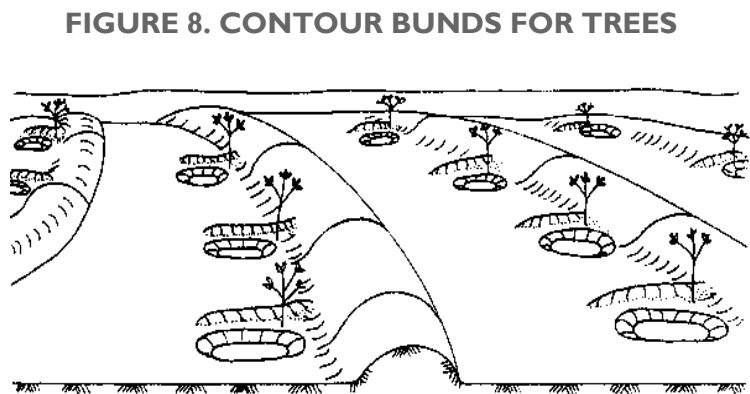
2.7 CONTOUR BUNDS

Contour bunds are used in crop agriculture and the establishment of trees. As the name indicates, the bunds are established following the contour, at close spacing. With the optional inclusion of small earth “ties,” formed laterally between the bunds, the system can be divided into individual microcatchments (see alternatively ACN and Contour Ridges/Tied Ridges). The construction of contour bunds lends itself to mechanization (animal traction and/or tractors). The technique is therefore suitable for implementation on a larger scale. Whether mechanized or not, this system is more economical than Negarim microcatchment, particularly for large-scale application - since less earth has to be moved. The major advantage of contour bunds is their suitability to crop cultivation between the bunds. As with other forms of microcatchment water harvesting techniques, the yield of runoff is high, and when designed correctly, there is no loss of runoff out of the system.

Technical details

The overall layout consists of a series of parallel, or almost parallel, earth bunds approximately on the contour at a spacing of between 5 and 10 meters.

1. If used for tree establishment, common sizes of microcatchments are around 10 -50 m² for each tree, otherwise crops can be sown in the entirety of the area between bunds.
2. Bund heights are in the order of 25 - 40 cm depending on the prevailing slope.
3. Bund should not be less than 25 cm in height. Base width must be at least 75 cm.
4. Bunds should be spaced at either 5 m or 10 m apart, depending on slope. It is recommended to provide 10 m spacing between the bunds on slopes of up to 0.5% and 5 m on steeper slopes.
5. If used, full or partial cross-ties (Figure 5) should be at least 2 meters long, at a spacing of 2 to 10 meters between ties.
6. An optional collection pit can be excavated in conjunction with the bund and the cross-tie. A pit size of 80 cm x 80 cm and 40 cm deep is usually sufficient.



Credit: Critchley & Siegert, with Chapman. (1991) FAO

Suitability

Rainfall: 200 - 750 mm; from semi-arid to arid areas.

Soils: Must be at least 1.5 m and preferably 2 m deep to ensure adequate root development and water storage if the system is used for tree planting.

Slopes: from flat up to 5.0%.

Topography: must be even, without gullies or rills.

Limitations: Contour bunds are not suitable for use on very uneven or highly eroded land as extreme storm events may lead to the collection of water in low spots, eventual breaching the bunds, trigger a washout of bunds downslope.

Sources

Critchley, W., & Siegert, K., with Chapman, C. (1991). "A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production." Food and Agriculture Organization: Rome.

Nagano, T., Horino, H., & Mitsuno, T. (2002). A study on conservation of millet field in the southwestern Niger, West Africa. In *Proceedings of 12th International Soil Conservation Conference, Beijing, China* (pp. 26-31).

2.8 AMÉNAGEMENT EN COURBES DE NIVEAU (ACN)

A variation in the use of contour bunds, the Aménagement en courbes de niveau (ACN) system is a holistic landscape approach to manage water and capture rainfall on a watershed scale. The approach was developed in Mali by researchers of the Institut d'Economie Rurale (IER) and Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD). The principal objectives of the ACN technology are to: capture and retrain rainfall in treated fields, and assist the evacuation of excessive rainfall and destructive surface flow that may run onto fields during heavy storm events.

IMAGE 2. FUNCTIONAL ADOS AND ANNUAL RIDGES IN A FARMER'S FIELD



Photo: USAID. SM CRSP Bulletin, University of Hawaii.

The system consists of establishing permanent ridges (Ados) about 100 cm wide that are constructed on the contour and maintained in subsequent years. Smaller ridges are then established through normal plowing that follow the contour indicated by the permanent Ados. Other structures may be required, such as overflow or evacuation channels to remove excessive water for the field. Treated fields can increase infiltration of rainwater by up to 10 per cent of the total annual rainfall, even in fields with a gentle slope between 1 to 3 per cent. The increased rates of water infiltration with ACN suggest that the reduction in surface runoff of rainwater results in greater capture and deeper percolation of water into the soil.

Technical details

1. A typical distance between the permanent ridges (Ados) ranges from 20 to 50 meters with distance between Ados decreasing with increasing slope.
2. If the slope is very flat, the maximum distance between the Ados will be 50 m. If the slope is steep, the Ados will be placed such that change in elevation between the Ados never exceeds 80 cm.

Suitability

1. In regions with high susceptibility to erosion due to low infiltration rate and high intensity of rainfall during the short rainy season.
2. In regions with evidence of widespread of severe erosion with slopes of 5 percent or less.

Source

Kablan, R., et al. (2008a). "Aménagement en courbes de niveau" (ACN): A water harvesting technology to increase rainfall capture, water storage, and deep drainage in soils of the Sahel." SM CRSP Bulletin, University of Hawaii. http://www.ctahr.hawaii.edu/sm-crsp/pubs/pdf/acnfiche_finaldraft_1.pdf

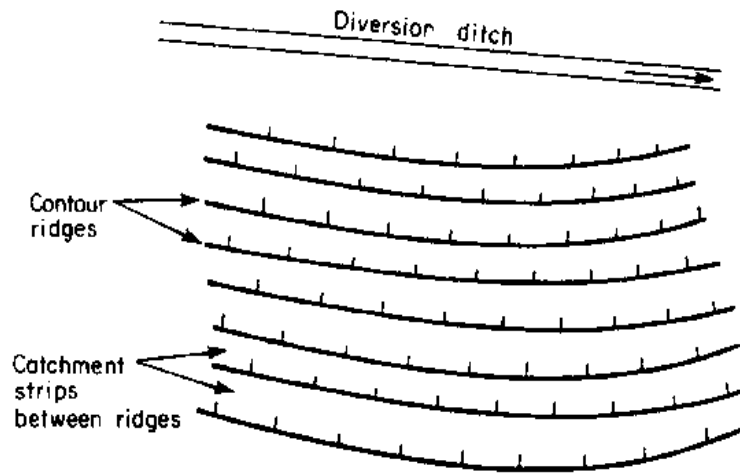
2.9 CONTOUR RIDGES/TIED RIDGES

Contour ridges, or contour plowing, are commonly used worldwide in crop production. This is again a microcatchment technique. Ridges follow the contour at a spacing of usually 1 to 2 meters. Runoff collects and is stored in the furrow between ridges. Crops are typically planted on the ridge tops. Additionally, ties can be added to the system, consisting of low ridged or barrier, between the principle ridges, thus creating micro-catchments within the furrows. The use of ties is helpful in preventing water from accumulating in low spots and potentially breaching ridges on slopes. The use of ties is particularly useful on undulating terrain, or in situations where precise contouring is not possible.

The system, with or without ties, is simple to construct and amenable to use with animal traction or tractors. Special attachments (for animal traction and tractors) are available to facilitate creation of “ties.”

The yield of runoff from the very short catchment lengths is extremely efficient and when designed and constructed correctly there should be no loss of runoff out of the system. Another advantage is an even crop growth due to the fact that each plant has approximately the same contributing catchment area.

FIGURE 9. COUNTOUR RIDGES, FIELD LAYOUT



Credit: Critchley & Siegert, with Chapman. (1991) FAO

Technical details

1. A spacing of 1-2 meters between ridges (C:CA ratios of 2:1 and 3:1 respectively) is generally recommended for annual crops in semi-arid areas (farmers tend to use narrower spacing, e.g., .75 cm).
2. If used, ties are commonly placed at 2 m intervals within the furrow.

Suitability

Rainfall: 350 - 750 mm.

Soils: all soils which are suitable for agriculture. Heavy and compacted soils may be a constraint to construction of ridges by hand.

Slopes: from flat up to 5.0%.

Topography: must be even - areas with rills or undulations should be avoided.

Limitations: If not carefully constructed contour ridges are susceptible to breaching during extreme storm events. In worse case scenarios poorly constructed or damaged ridges can fail, leading to a

“cascading” effect where subsequent ridges downslope become overloaded and break, one after and another

Sources

Critchley, W. & Siegert, K., with Chapman, C. (1991). “A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production.” Food and Agriculture Organization: Rome.

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2.10 PERMEABLE ROCK DAMS

Permeable rock dams are a farming technique for spreading floodwater for improved crop production. The development of gullies can be stemmed at the same time. Permeable rock dams can be considered a form of “terraced wadi”, though the latter term is normally used for structures within watercourses in more arid areas.

A permeable rock dam is a long, low structure, made from loose stone or gabion baskets that extend across a valley floor or drainage. The central part of the dam is perpendicular to the watercourse, while the extensions of the walls to either side typically curve back up the valley. The idea is that the runoff concentrating in the center of the valley, will be spread and retained across the whole valley floor, thus making conditions more favorable for plant growth, especially rice cultivation. Excess water spills over the top of the dam during peak flows, while the remainder slowly filters through the dam. Often a series of dams are built along the same valley floor, giving stability to the valley system as a whole.

Interest in permeable rock dams had centered on West Africa - Burkina Faso in particular - and had grown substantially in the latter part of the 1980s. This technique —“*digue filtrante*” in French — was particularly popular where villagers had experienced the gullying of previously productive valley bottoms, resulting in floodwater no longer spreading naturally. The large amount of work involved means that the technique is labor intensive and needs a group approach, as well as assistance with transport of stone and other materials.

Technical details

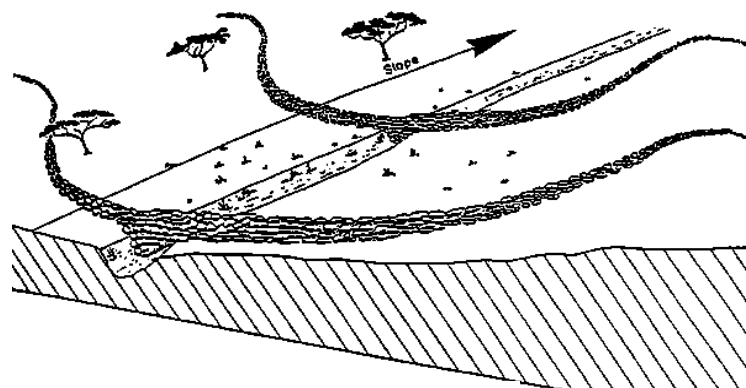
1. The main part of the dam wall is usually about 70 cm high although some are as low as 50 cm. However, the central portion of the dam including the spillway (if required) may reach a maximum height of 2 m or more above the valley floor. The dam wall or “spreader” can extend up to 1000 meters across the widest valley beds, but the lengths normally range from 50 to 300 meters. The amount of stone used in the largest structures can be up to 2000 tons.

IMAGE 3. PERMEABLE ROCK DAM,
BURKINA FASO



Photo: B.M. Simpson

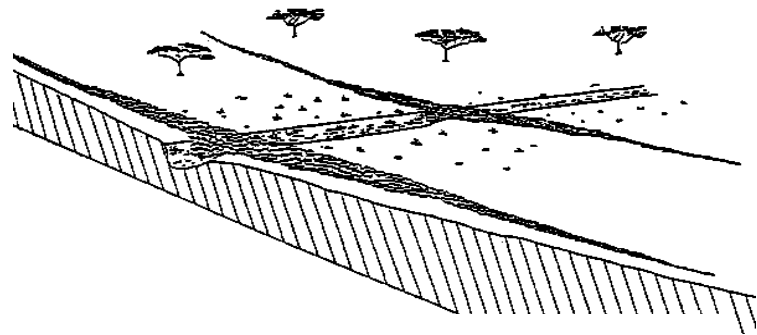
FIGURE 10. PERMEABLE ROCK DAM,
GENERAL LAYOUT



Credit: Critchley & Reij, FAO (1989)

2. The dam wall is made from loose stone, or gabion, carefully positioned, with larger boulders forming the “framework” and smaller stones packed in the middle like a “sandwich”. The side slopes are usually 3:1 or 2:1 (horizontal: vertical) on the downstream side, and 1:1 or 1:2 on the upstream side. With shallower side slopes, the structure is more stable, but more expensive.

FIGURE 11. PERMEABLE ROCK DAM, ALTERNATIVE LAYOUT.



3. For all soil types it is recommended to set the dam wall in an excavated trench of about 10 cm depth to prevent undermining by runoff waters. In erodible soils, it is advisable to place a layer of gravel, or at least smaller stones, in the trench. *Source: Critchley & Reij, FAO (1989)*
4. Design variation: Where permeable rock dams are constructed in wide, relatively flat valley floors, they are sometimes made straight across — in contrast to the usual design where the spreader bunds arch back up the valley from the center following the contour. With straight dams, the height of the wall decreases from the center towards the sides of the valley to maintain a level crest.

Suitability

Rainfall: 200 -750 mm; from arid to semi-arid areas.

Soils: all agricultural soils - poorer soils will be improved by treatment.

Slopes: best below 2% for most effective water spreading.

Topography: wide, shallow valley beds.

Limitation: very site-specific require considerable quantities of loose stone as well as the provision of transport and are very labor intensive.

Sources

Critchley, W. and K. Siegert, with C. Chapman. (1991). “A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production.” Food and Agriculture Organization: Rome.

Tabor, J. A. (1995). Improving crop yields in the Sahel by means of water-harvesting. *Journal of Arid Environments*, 30(1): 83-106.

2.11 VEGETATIVE STRIPS

The use of vegetative strips, either naturally occurring or planted, is a traditional practice to demarcate and protect fields used by farmers in various parts of Africa. The recommended use of contour barrier vegetative barriers and hedge-rows of multipurpose trees have been promoted in various forms since the 1980's.

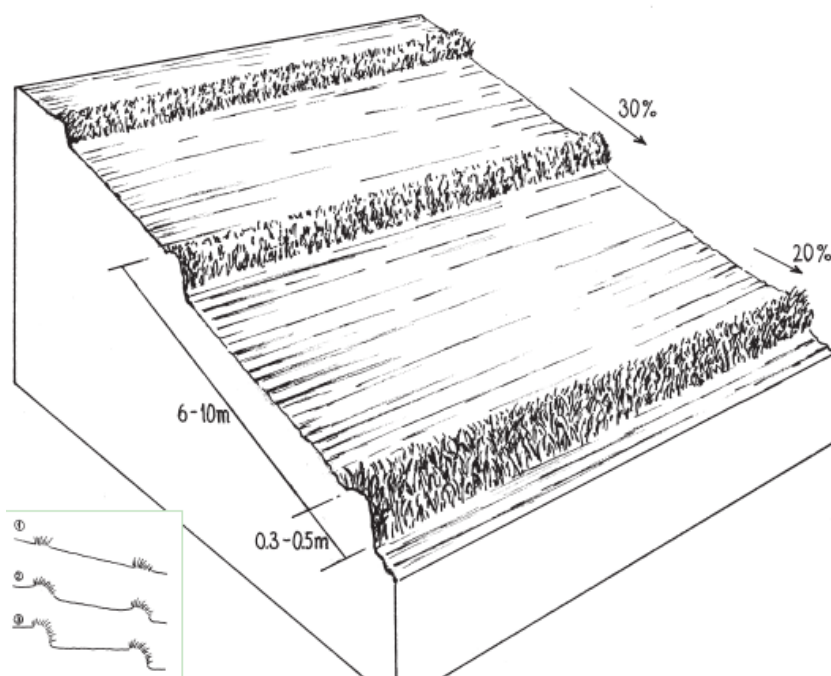
Technically, vegetative strips are narrow bands of naturally occurring or planted grasses, other plants and trees. Contour lines are laid out and staked to serve as an initial guide for ploughing, with wide strips left unploughed to allow vegetation to establish. Alternatively, the staked contours are used to guide the planting of species, such as vetiver grass. In either case, rainfall runoff flowing down slope is slowed, and infiltrates when it reaches the vegetative strips. As the water movement slows, suspended soil particles collect above the strips and natural terraces form overtime. This levelling is assisted by ploughing along the contour between the strip which causes some 'tillage erosion' that also moves soil downslope. Vegetative strips constitute a low-cost technique with modest labor demands for establishment and maintenance.

Land users appreciate the technique because it effectively controls soil erosion and prevents loss (through surface runoff) of fertilizers applied to the crop. As an option, some farmers plant fruit and timber trees, bananas or pineapples on or above the vegetative strip. This may be during establishment of the contour lines, or later. The trees and other cash perennials provide an additional source of income, at the cost of some shading of the adjacent annual crops.

Technical Details

1. Natural vegetative strips and mature vetiver hedges are 0.3—0.5 m wide.
2. Natural vegetation in the established strips needs to be cut back to a height of 5-10 cm once or twice during the cropping period. Vetiver grass should be maintained at 30-50 cm. Natural grass that is cut can be applied as mulch or used as livestock feed depending on the composition. Before planting vetiver plants are cutback to 15-20 cm and the roots 10 cm below.

FIGURE 12. VEGETATIVE STRIPS



Spacing of natural vegetative strips depends on the slope. The insert shows the evolution of terraces over time through tillage and soil erosion, leading to accumulation of sediment behind the strip.

Source: WOCAT, Liniger, H., & Critchley, W. (2007)

3. Spacing between vetiver plants within a row is 20 cm. Spacing of rows of vetiver or natural vegetative strips depends on the slope. Recommendations have been made for the establishment of a strip for each 2 m of vertical drop.

Suitability

Annual rainfall: up to 1500-3000 mm

Slope: moderate (5%-8%) to steep (40%-70%)

Soil fertility: Soil with high P fixing capacity

Soil type: texture mostly loamy or fine, along with partly stony or no stones on the surface

Topsoil organic matter: mostly low (<1%), partly medium (1—3%)

Soil drainage: generally good except in depressions

Soil erodibility: medium to high

Soil depth : 20cm -120 cm

Sources

GIZ (2012). Good Practices in Soil and Water Conservation: A contribution to adaptation and farmers' resilience towards climate change in the Sahel.

Liniger, H. & Critchley, W. (2007), Where the land is greener — case studies and analysis of soil and water conservation initiatives worldwide. World Overview of Conservation Approaches and Technologies (WOCAT).

Liniger, H.P., Mekdaschi Studer, R., Hauert, C., & Gurtner, M. (2011). Sustainable Land Management in Practice — Guidelines and Best Practices for Sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO): Rome.

White, L. P. (1971). Vegetation stripes on sheet wash surfaces. *The Journal of Ecology*, 615-622.

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2.12 VALLERANI SYSTEM

The Vallerani System (VS) is a relatively new system of water harvesting where a special tractor pulled plough is used to automatically construct water-harvesting catchments. This system is ideally suited for large-scale reclamation work. The Vallerani implement is a modified plough named Delfino3, pulled by a heavy-duty tractor. The Delfino3 plough has a single reversible ploughshare that creates an angled furrow and piles up the excavated soil on the lower (downhill) side of the furrow. This soil forms a ridge that stops or slows down runoff water as it flows downhill.

The Vallerani System is intended for use with direct sowing of seeds of shrubs and trees. Seeds are sown along the ridges of the basins and in the wake of the ripper. With more moisture available for a longer period of time trees grow rapidly and the herbaceous cover improves in quality and in quantity - providing 20-30 times more livestock fodder (1,000-2,000kg dry herbaceous biomass ha/year), also helping to conserve the soil.

IMAGE 4. VALLERANI MICROCATCHMENTS



Source: Photo: W. Critchley, from Mekdaschi Studer, R., & Liniger, H. (2013)

Technical details

1. The plough's blade moves up and down (i.e. in and out of the soil), creating micro-basins about 5 meters long, 50 cm deep and spaced about 2 m, each with a ridge.
2. Two rippers placed before the plough work the soil to a depth of 80 cm, allowing the micro-basin to be created by the plow blade.
3. Even with very low rainfall (150-500 mm/year) each micro-basin/storage bag can collect 1,500 litres of water, including runoff. This water is protected against evaporation and remains available to plant roots and groundwater.
4. The Vallerani plough can 'treat' up to 20 ha, digging 5,720 micro-basins, in a single day. The speed and effectiveness of the Delfino3 plough are its major advantages.

Suitability

Rainfall: 250-750 mm

Altitude: 100-1000 m.a.s.l

Landform: valley, plateau/ plains

Slope: flat

Soil depth: 0-20 cm

Availability of surface water: poor, good

Soil water storage capacity: good, low

Soil texture: light (sandy), coarse

Soil organic matter: good, low

Top soil organic matter: possible even under 1%

Soil drainage/infiltration: good, poor

Limitation: In order to be cost effective, use of the system requires large land areas to be treated.

Sources

Mekdaschi Studer, R., & Liniger, H. (2013) Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome.

Schmidt, M., König, K., Hahn, K., Zizka, G., & Wittig, R. (2010). Restoration of Bare Incrusted Soils in the Sahel Region of Burkina Faso. *Flora et Vegetatio Sudano-Sambesica* 13: 3-9.

Vallerani system website. <http://www.vallerani.com/wp/>

2.13 PLANTING TRENCHES

The main purpose of this technique is to restore tree cover and prevent water erosion on slopes by reducing the flow of water that threatens land downstream areas. The established trenches reduce gully erosion and pedimentation of areas with a fragile soil structure. It permits the reintroduction of trees on degraded, unfertile land and contributes to dissipating the force of runoff flow and increases infiltration. Areas restored using planting trenches can subsequently be exploited to a limited extent in accordance with careful management practices. The infiltration of water in planting trenches can also contribute to groundwater recharge.

This technique has proved effective in restoring forest/ rangeland on highly degraded sites. The progressive development of grass and tree cover continues on these sites for years after establishment. However, the young trees must be monitored for several years to ensure that they are not damaged by stray grazing animals, and any dead trees must be replaced.

IMAGE 5. DESIGN OF HAND-DUG TRENCHES



Photo: GIZ, 2012

Technical details

1. Length of the trench is 3-3.5 m
2. Depth is around 0.6 m
3. Space between trenches is around 4 m in staggered row resulting in around 625 trenches per hectare
4. The excavated earth is piled downhill of the trenches, which are aligned perpendicular to the slope. In the middle of each trench, a 0.40 m high “step” is left on which the tree seedling is planted. The tree receives the water it needs from the trench where it collects. The plants are safe in case of a violent downpour as they are located above the trench bottom to avoid waterlogging.

Suitability

This technique is designed to restore communal land on slopes and highland pediments.

Useful in locations where rainfall is low, as the trenches retain water and make it available to the trees growing in them.

Best suited for highly degraded land with low fertility. The high labor demands are a drawback.

Source

GIZ. (2012). Good Practices in Soil and Water Conservation: A contribution to adaptation and farmers' resilience towards climate change in the Sahel.

2.14 FARMER MANAGED/ASSISTED NATURAL REGENERATION

The most famous application of Farmer Managed Natural Regeneration (FMNR) occurred in the Maradi region, Niger, beginning in the early 1980's and ultimately covering more than 50,000 ha in Niger. FMNR is the systematic regeneration of living stumps and emergent seedling of indigenous trees, which previously had been slashed and burned in field preparation. Most suitable are species with deep roots that do not compete with crops and have good growth performance even during poor rainy seasons. FMNR is a simple, low-cost method of re-vegetation, accessible to all farmers, and adapted to the needs of smallholders. It reduces dependency on external inputs, is easy to practice and provides multiple benefits to people, livestock, crops and the environment.

More broadly FMNR represents a broad category of practice, and thus does not adhere to specific fixed technical aspects and suitability criteria. There are different FMNR practices for different agro-climatic zones and farming systems.

Sources

- Haglund, E., Ndjeunga, J., Snook, L., & Pasternak, D. (2011). Dry land tree management for improved household livelihoods: Farmer managed natural regeneration in Niger. *Journal of environmental management*, 92(7): 1696-1705.
- Liniger, H.P., Mekdaschi Studer, R., Hauert, C., & Gurtner, M. (2011). Sustainable Land Management in Practice – Guidelines and Best Practices for Sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO): Rome.

2.15 PLANTING PITS

The construction of planting pits, also known as *Zai* or *tassa* holes, are a traditional practice in various location of Africa. In West Africa the promotion *Zai* holes became popular in the early 1980s based on refinements to traditional practices in Burkina Faso. Traditionally, planting pits were used on a small scale to rehabilitate barren land (*zipélé*), hardpan areas where rainfall could no longer infiltrate. The dimensions of the pits were increased (from a diameter of 10 – 15 cm to 20 – 30 cm and a depth of about 20 cm). Another innovation was the recommendation of adding manure to the holes. In this way the improved planting pits concentrated water and nutrients in one spot; the underlying principles of conservation agriculture.

IMAGE 6. PLANTING PITS (TASSA) BEFORE PLANTING AND RAINY SEASON, NIGER.



Photo: H.P.Liniger.

The pits are dug during the dry season and the organic material is used to attract termites. Termites play a crucial role as they dig channels in the soil and by doing so they improve soil structure. At the same time they digest the organic matter and make nutrients more easily available to the crops planted or sown in the pits.

Planting pits are used for the rehabilitation of degraded, crusted land. They are dug by hand, with the excavated earth is formed into a small ridge downslope of the pit for maximum capture of rainfall runoff. Manure is added to each pit, though its availability can be a problem. The improved infiltration and increased nutrient availability brings degraded land into cultivation. The technology does not require external inputs or heavy machinery and is therefore easily adopted. *Zai* holes are often combined with stone lines along the contour to further enhance water infiltration, reduce soil erosion and siltation of the pits. Grass growing between the stones helps increase infiltration further and accelerates the accumulation of fertile sediment.

Technical details

1. Planting pits are holes of 20-30 cm diameter and 20-25 cm depth, spaced about 1 m apart in each direction.
2. Generally the shape of the pit is circular, but it can be fabricated in other shapes.

Suitability

Average annual rainfall: semi-arid 250-500 mm

Soil type: sandy, shallow soil

Soil drainage: well drained

Fertility: effective even in low to very low fertility

Organic matter: effective even in low organic matter (less than 1%)

Landform: mainly plains / plateaus, partly foot slopes

Slope: mostly gentle (2-5%), partly flat (0-2%)

Sources

Kaboré, D., & Reij, C. (2004). *The emergence and spreading of an improved traditional soil and water conservation practice in Burkina Faso*. Conference Paper No. 10

Liniger, H.P., Mekdaschi Studer, R., Hauert, C., & Gurtner, M. (2011). Sustainable Land Management in Practice – Guidelines and Best Practices for Sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO): Rome.

Mekdaschi Studer, R. & Liniger, H. (2013) Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome.

3.0 SUPPLEMENTAL WATER SUPPLY

3.1 GOUTE-A-GOUTE (DRIP IRRIGATION)

Modern drip irrigation began its development in Germany in 1860 when researchers began experimenting with subsurface irrigation using clay pipe to create a combination of irrigation and drainage systems. Research was later expanded in the 1920s to include the application of perforated pipe systems. The usage of plastic to hold and distribute water in drip irrigation was later developed in Australia.

Drip irrigation involves releasing water into the soil at very low rates (2-20 litres/hour) from a system of small diameter plastic pipes fitted with outlets called emitters or drippers. Water is applied close to plants so that only part of the soil in which the roots grow is wetted unlike surface and sprinkler irrigation, which involves wetting the entire soil surface. Drip irrigation achieves very high irrigation efficiency with up to 90% of the applied water being available to the plants. It is especially useful in context of low water availability, high demands and/or costs for irrigation water. With drip irrigation water applications are more frequent (usually every 1-3 days) than with other methods and this provides very favorable soil conditions where plants can flourish.

IMAGE 7. GRAVITY-FEED DRIP IRRIGATION SYSTEM



Indigenous drip system, Burkina Faso.

Source: Sogoba et al., 2012.

Technical details

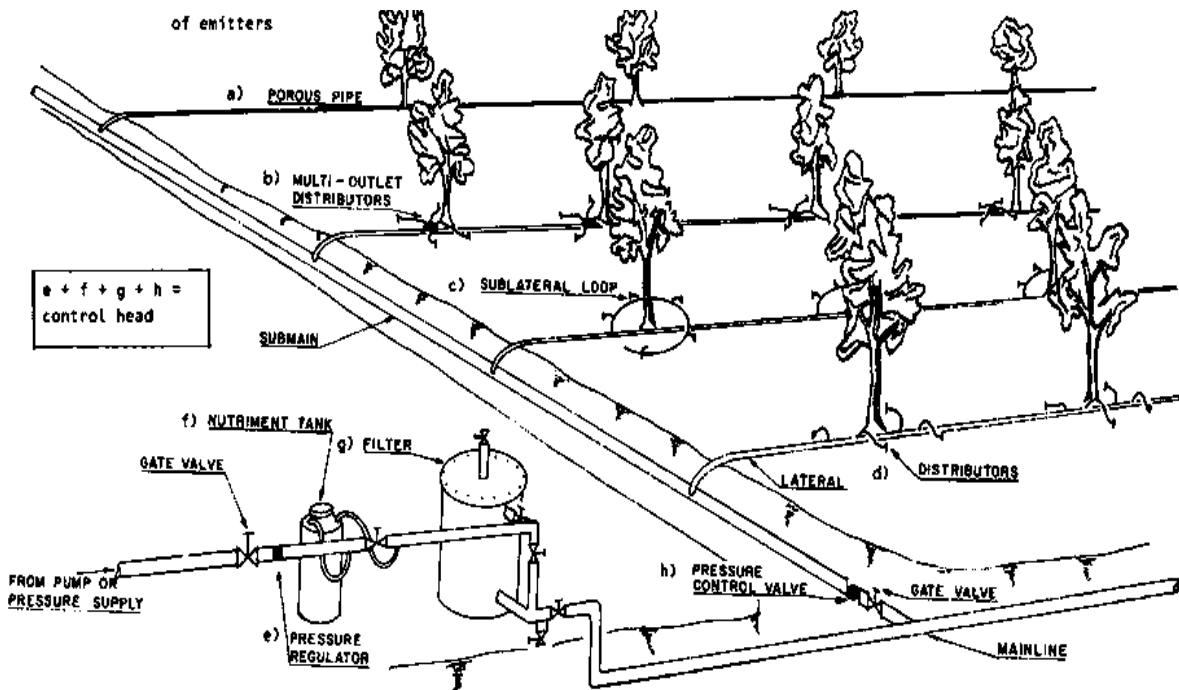
In systems using a pump, the pump unit takes water from a source and provides the correct pressure for delivery into the pipe system. In gravity flow systems, more commonly found in West Africa, water is pumped into an elevated reservoir from which it is distributed throughout the system. Due to the weaker pressure, gravity fed systems are smaller, with fewer branches.

1. The control head consists of valves to control the discharge and pressure in the entire system. It may also have filters to clear the water. Common types of filter include screen filters and graded sand filters that remove fine material suspended in the water. Some control head units contain a fertilizer or nutrient tank. These slowly add a measured dose of fertilizer into the water during irrigation. This is one of the major advantages of drip irrigation over other methods.
2. Mainlines, submains, and laterals supply water from the control head into the fields. They are usually made from PVC or polyethylene hose and should be buried below ground because they easily

degrade when exposed to direct solar radiation and are exposed to animal damage. Lateral pipes are usually 13-32 mm diameter.

3. Emitters or drippers are devices used to control the discharge of water from the lateral to the plants. They are usually spaced more than 1 meter apart with one or more emitters used for a single plant such as a tree. For row crops more closely spaced emitters may be used to wet a strip of soil. Many different emitter designs have been produced in recent years. The underlying design principle is to produce an emitter that will provide a specified, constant discharge that does not vary much

FIGURE 13. GRAVITY FED DRIP IRRIGATION WITH DIFFERENT TYPES OF EMITTERS



Source:

<http://www.millenniumland.com/images/LANDSCAPE%20SERVICES/Irrigation/Drip%20Irrigation%20Systems/Drip%20Irrigation.gif>

Suitability

1. Crops: Drip irrigation is most suitable for row crops (vegetables, soft fruit), tree and vine crops where one or more emitters can be provided for each plant. Generally only high value crops are considered because of the high capital costs of installing a drip system.
2. Slope: Drip irrigation is adaptable to any farmable slope. Normally the crop would be planted along contour lines and the water supply pipes (laterals) would be laid along the contour also. This is done to minimize changes in emitter discharge as a result of land elevation changes. In gravity fed systems, the supply reservoir is placed uphill to add water delivery through the system.
3. Soil: Drip irrigation is suitable for most soils. On clay soils water must be applied slowly to avoid surface water ponding and runoff. On sandy soils higher emitter discharge rates will be needed to ensure adequate lateral wetting of the soil.

4. Irrigation water: One of the main problems with drip irrigation is blockage of the emitters. All emitters have very small waterways ranging from 0.2-2.0 mm in diameter and these can become blocked if the water is not clean. Thus it is essential for irrigation water to be free of sediments. If particle free water is not available, then filtration of the irrigation water will be needed. Blockage may also occur if the water contains algae, fertilizer deposits and dissolved chemicals that precipitate such as calcium and iron. Filtration may remove some of the materials but the problem may be complex to solve and requires an experienced engineer or consultation with the equipment dealer.

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Goldberg, D., Gornat, B., & Rimon, D. (1976). Drip irrigation: principles, design and agricultural practices. Drip irrigation: principles, design and agricultural practices.

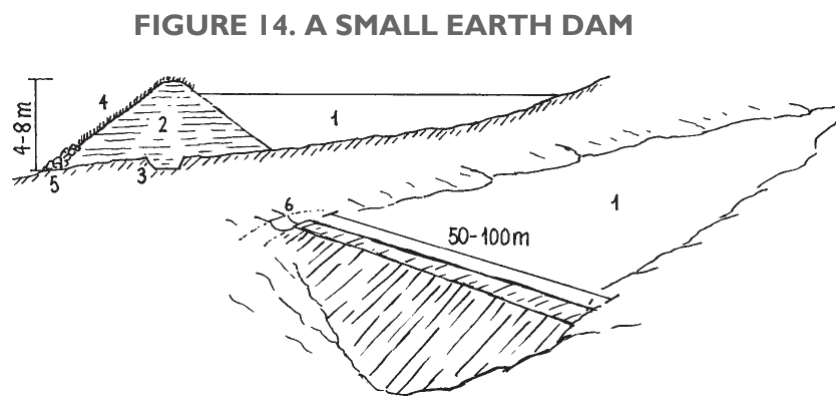
3.2 SMALL EARTH DAMS

Small earth dams are water harvesting storage structures, constructed across narrow sections of valleys, to impound runoff generated from upstream catchment areas. Construction of the dam wall begins with excavation of a core trench along the length of the dam wall that is filled with clay and compacted to form a central core (“key”) that anchors the wall and prevents or minimizes seepage. The upstream and downstream embankments are built using soil with 20-30% clay content. During construction – either by human labor, animal draught or machine (bulldozer, compacter, grader etc.) – it is critical to ensure good compaction for stability of the wall. It is common to plant Kikuyu grass (*Pennisetum clandestinum*) to prevent erosion of the embankment. Fencing may be required to prevent livestock from eroding the dam wall.

Direct benefits of small dams include increased water availability, in terms of volume and duration, for pump-based irrigation, and recharge of groundwater aquifers reduced downstream flooding.

Technical details

1. Typical length of the embankment is 50-100 m with water depth ranging 4-8 m.
2. An emergency spillway (vegetated or a concrete chute) is provided on either, or both sides, of the wall for safe disposal of excess water above the full supply level.
3. Dams have usually a maximum impoundment area of 500 m from the dam wall, with a capacity ranging from 50,000 – 100,000 m³



Dimensions and main components of a small dam: (1) water body; (2) dam wall (with layers of compacted soil; side slopes, 3:1); (3) central core (“key”); (4) grass cover; (5) stone apron; (6) spillway.

Source: Liniger, H.P., et al. (2011).

Suitability

Climate: semi-arid, subhumid

Average annual rainfall: 400-800 mm

Soil drainage: well drained

Soil texture: loamy to sandy soil

Slope: plains (2-15%) and valleys (15-40%)

Landform: plains and valleys

Sources

- Liniger, H.P., R. Mekdaschi Studer, C. Hauert and M. Gurtner. (2011). Sustainable Land Management in Practice – Guidelines and Best Practices for Sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO): Rome.
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- Tabor, J. A. “Improving crop yields in the Sahel by means of water-harvesting”, *Journal of Arid Environments*, (30, 1) May 1995

3.3 CHECK DAMS

A variation of small dam technology is the check dam. Check dams are small barriers or dam constructed across a swale, drainage or other area of intermittent concentrated flow for the purpose of reducing channel erosion and slowing the evacuation of water. Most check dams are constructed of rock, but hay bales, logs, concrete, metal and other materials may be used. The dams are small-scale investments, best targeted for impoundment areas less than 10 acres. The water retained by check dams can be used as a source form pump-based irrigation, livestock watering holes and other purposes

IMAGE 8. CHECK DAM



Check dams made of stone, concrete, and gabion, for irrigation. Such dams also reduce runoff velocity, enhancing gully rehabilitation.

Photo: E. Yazew.

Technical details

1. The width of the dam wall ranges between 1 – 2 m.
2. Height of the dam varies between 2– 4 m depending upon the gully depth.
3. The length of the check dam depends on the gully width while the spacing between adjacent check dams is determined based on the availability of water and a potential land that can be irrigated.
4. The gully area needs to be well protected against further erosion. Otherwise the dam will be quickly filled with sediments.

Suitability

Arid, semi-arid to sub-humid zones where it is necessary to store water to bridge the dry season or to mitigate the impact of dry spells.

Slope: plains (2-15%) and valleys (15-40%); Landform: plains and valleys.

Sources

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3.4 PUMP-BASED IRRIGATION SCHEMES

Pump-based irrigation schemes use water from nearby sources to deliver water to an irrigation canal system. The pump units are typically mobile, technologically filling the space between smaller individual field irrigation units, and larger fixed installations. Depending on the topology, water is pumped into the stilling basin, allowing gravity to then move water into the canal network, or pumped directly into fields. Irrigation systems of this kind were introduced into Mali following the 1970 droughts through various development projects targeting rice and wheat production. Between 1996 and 2010, for example, the Instituto Provincial de Discapacidad (IPRODI) project established 450 irrigation schemes in northern Mali, creating an irrigated area of over 13,000 ha farmed by 55,000 farmers. This technique makes it possible to develop unirrigated land at relatively low cost.

IMAGE 9. PUMP FOR VILLAGE IRRIGATION, MALI



Photo: GIZ. (2012).

Pump-based systems are able to irrigate areas of between 20 and 40 hectares, surrounded by low earthen dikes. A typical system design includes a stilling basin, which receives water from a motor pump, a main channel, secondary channels and irrigation ditches. The scheme gives total control over the water availability within the system by moving the pump to different pumping stations around the system. The channels are open earth, and stretches where infiltration is high can be lined with riprap, or concrete. Water control structures are made of concrete. Such schemes require a secure source of water, and thus are generally located along rivers or near (semi-) permanent bodies of water. Such systems are vulnerable to fuel availability and cost.

Suitability

1. Village irrigation schemes are suitable for sites with a permanent source of water nearby
2. It is preferred if there is a little difference in level of the water source and areas to be irrigated, as this reduces pumping costs.
3. Pump-based systems are also facilitated by easy access to fuel supply.

Source

GIZ. (2012). Good Practices in Soil and Water Conservation, A contribution to adaptation and farmers' resilience towards climate change in the Sahel.

3.5 BAS FONDS DEVELOPMENT (LOWLAND / WETLAND DEVELOPMENT)

In areas where rainfall is a constraint, the agricultural value of *bas fonds* (lowland areas) is high due to the fact that these areas retain critical moisture far into, and sometimes throughout, the dry season. *Bas fonds* are found in a range of forms and positions in the landscape. In general they function as “receiving sites” in terms of soil, hydrological, and slope processes.

In Burkina Faso and other Sahelian countries an increased intensity of *bas fond* use has been observed since the 1970s. During the wetter period up to the 1970s, and when population densities were relatively low, extensive rain-fed cultivation was sufficient for food in both good and bad years. Relative land abundance made shifting cultivation feasible; the *bas fonds* were generally avoided as sites for cultivation as the effort involved in clearing and weeding was too great. Under these conditions, the *bas fonds* were often left for animal grazing, fuelwood production, wild fruit and water collection. Since the 1970s, as land pressures have increased and rainfall declined, cultivators have moved down the catena to exploit the more productive and stable *bas fonds*.

The problem in evaluating the development potential of prospective areas is the dynamic nature of water availability, since water tables fluctuate over several meters during the course of a year, and in differing patterns between years. It depends on the entire watershed, as well as the topographic situation of the *bas fond*, as to whether a particular *bas fonds* will receive sufficient water during the dry season to produce a viable crop.

Technical details

The development of *bas fonds* ranges from the construction of a single, or series of low (<80 cm), earthen dikes across a valley bottom, to a central barrier with interior dikes, and water control structures. When well built, *bas fonds* can achieve high levels of water control and support excellent rice harvests. The Diagnostic Rapide Pré-Aménagement (DIARPA) assessment tool was developed by CIRAD researchers and published through the Inland Valley Consortium (Africa Rice) to assist identification of the least-cost water control structures based upon valley bottom width, slope, depth of under laying clay layer and stream flow.

Suitability

Rainfall: 700-1200 mm

Landform: valley floor

Slope: gentle slope

Soil water storage capacity: Medium to very high.

Soil drainage: productive soils, with underlying clay layer.

IMAGE 10. BAS FONDS



Photo: B.M. Simpson (Mali)

Source

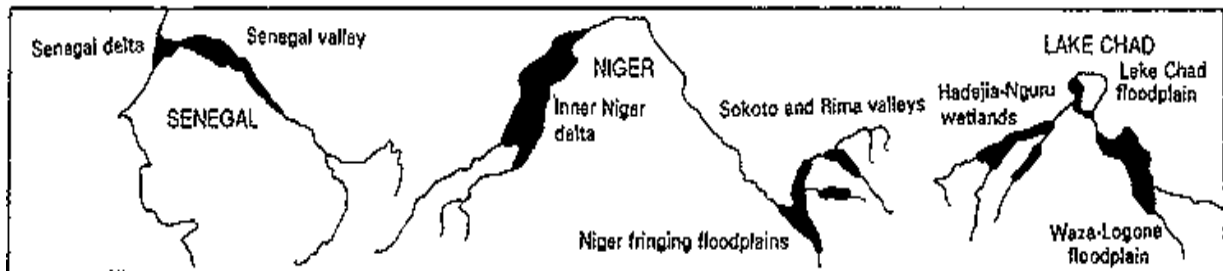
Scoones, I. (1991). "Wetlands in Drylands: Key Resources for Agricultural and Pastoral Production in Africa" *Ambio*, Vol. 20 (8): 366-371.

3.6 FLOOD PLAIN DEVELOPMENT

Lack of sufficient water is one of the major factors limiting agricultural development in the drier areas of West Africa. Though this region experiences low and highly seasonal rainfall, during the wet season's large areas adjacent to the major rivers — including the Senegal, Niger, Yobe, and Logone rivers — and their tributaries become inundated. For centuries, these floodplains have played a central role in the rural economy of the region providing fertile agricultural land. The floodwaters bring essential moisture and nutrients to the soil, and in areas provide important breeding grounds for fish. Water, soaking through the floodplain recharges the underground reservoirs that supply water to wells downstream and outside of the wetland. Agricultural activity is at its height as the floodwaters recede, but sufficient soil moisture persists to the dry season and provides essential grazing for migrant herds.

Technically, the development of flood plains, which can cover hundreds to well over a thousand hectares, presents a scaled-up version of the *bas fonds*. The larger systems often have internal dikes and water control structures to facilitate and control the flooding. Within the different compartments, such systems resemble vast open plains. The characteristics of each specific site make it difficult to make detailed generalizations.

FIGURE 15. MAJOR FLOODPLAINS OF SAHELIAN WEST AFRICA



Source: Acreman, M.C. (1996)

Suitability

Rainfall: 700-1200 mm.

Landform: large, flat plains.

Slope: gentle slope to flat; Soil: productive agricultural soils.

Soil drainage: underlying clay layer.

Sources

Acreman, A.C. (1996) The IUCN Sahelian Floodplain Initiative: Networking to Build Capacity to Manage Sahelian Floodplain Resources Sustainably, *International Journal of Water Resources Development*, 12:4, 429-436

Dugan, P. (1990). *Wetland Conservation. A Review of Current Issues and Required Action*. Gland, Switzerland: IUCN.

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<http://www.friendsoftheriver.org/fotr/BeyondFloodControl/no1.html>

4.0 SOIL FERTILITY ENHANCEMENT

4.1 SYSTEM OF RICE INTENSIFICATION (SRI)

The *System of Rice Intensification*, known as SRI—*le Système de Riziculture Intensive* in French, *la Sistema Intensivo de Cultivo Arrocero* (SICA) in Spanish—is an agroecological-based production methodology for increasing the productivity of land and water. The practices were developed in Madagascar in early 1980's and integrated into a single approach by the mid-1980s.

SRI is based on the principle of developing a healthy, large and deep root system that can better resist drought, water logging and wind damage. It consists of four key elements (see below) to better manage inputs, utilize new ways to transplant seedlings, and to manage water and fertilizer application. Using the SRI methodology, yields are increased by 50-100% or more, while reducing inputs (seed by 90%, irrigation water by 30-50%, chemical fertilizer by 20-100%). For the farmer, SRI brings greater returns to labor, land and capital.

Technical details

1. **Seedlings:** Rice seedlings are carefully managed in nurseries and at an age of 8-12 days they are transplanted, one seedling per pocket, at wide spaces from 25-25 cm to 50-50 cm. With more space in which to grow, rice plants' roots become larger and are better able to draw nutrients from the soil. This enables rice plants to produce more grains.
2. **The soil:** Soil fertility is enriched through application of organic matter to improve soil structure, nutrient and water-holding capacity and favor soil microbial development. Organic matter represents the base fertilization for the crop and is complemented if needed by chemical fertilizer.
3. **Water:** Only a minimum of water is applied during the vegetative growth period. A 1-2 cm layer of water is introduced into the paddy, followed by letting the plot dry until cracks become visible, at which time another thin layer of water is introduced. During flowering a thin layer of water is maintained, followed by alternate wetting and drying in the grain filling period, before draining the paddy 2-3 weeks before harvest.
4. **Weeding:** While avoiding flooded conditions in the rice fields, weeds grow more vigorously, and need to be kept under control. Under the SRI system a rotary hoe - a simple, inexpensive, mechanical push-weeder — is recommended. Weeding starts at 10 days after transplanting, repeated ideally every 7-10 days until the canopy is closed. The rotary hoe also aerates the soil, important for maintain a healthy soil environment and root growth.

Suitability

SRI is suitable to most contexts where irrigated rice is produced. However, it is not suitable for saline or alkaline soils. Areas that are flooded during the cropping season, and where there is no way control water levels are not suitable. SRI requires abundant organic matter and/compost, and is generally believed to be more labor intensive than other production systems.

Sources

Krupnik, T. J., Shennan, C., & Rodenburg, J. (2012). Yield, water productivity and nutrient balances under the System of Rice Intensification and Recommended Management Practices in the Sahel. *Field Crops Research* 130: 155-167.

Cornell University College of Agriculture and Life Sciences. SRI Methodologies web page. SRI International Network and Resources Center.
<http://sri.ciifad.cornell.edu/aboutsri/methods/index.html#basicmgmtpractices>

4.2 AGROFORESTRY

Agroforestry (AF) is a collective name for management practices in which woody perennials are integrated with agricultural crops and/or livestock for a variety of benefits and services. AF ranges from very simple and sparse to very complex and dense systems. It embraces a wide range of practices: alley cropping, farming with trees on contours, or perimeter fencing with trees, multi-story cropping, relay cropping, intercropping, multiple cropping, bush and tree fallows, parkland systems, home gardens etc.; many of them are traditional land-use systems, or derived from traditional practices. Some important AF types include:

Agroforestry parkland systems are cropland areas interspersed with self-generating, indigenous tree species. Among the characteristics of traditional agroforestry parklands are the diversity of tree species, and the variety of products and uses (including fruits, fodder, etc.). They generate and provide favorable micro-climates (through shade especially) and buffer extreme conditions (through acting as windbreaks). Parklands are found primarily in the semi-arid and subhumid zones of West Africa. *Vitellaria paradoxa*, *Parkia biglobosa*, and *Faidherbia albida* cereal systems are common across millions of hectares in the Sahelian zone.

Multistory systems are existing or planted stands of trees or shrubs that are managed as an upper-story with one or more under-stories that are grown for a variety of products. The purpose is (a) to use different layers and improve crop diversity by growing mixed but compatible crops of different heights in the same area; (b) protect soils and provide a favorable micro-climate; (c) improve soil quality by increasing utilization and cycling of nutrients and maintaining or increasing soil organic matter and (d) increase carbon storage in plant biomass and soil. Moisture competition limits use of multistory cropping in the Sahel.

Fodder banks: Trees and shrubs with palatable leaves and/or pods are attractive as feed supplements for livestock. They can be grown on boundaries or pathways (often pollarded to reduce competition) and along field contours to curb soil erosion. Managing fodder shrubs requires multiple skills including raising seedlings in a nursery, pruning trees, and feeding the leaves. Over the past 10 years, over 200,000 farmers in Kenya, Uganda, Rwanda, and northern Tanzania have planted fodder shrubs, mostly to feed dairy cows. Extensive use of the practice has yet to be established in West Africa.

Improved fallows involve the planting of tree species in order to restore fertility within a short time. Natural vegetation can be slow in restoring soil productivity. By contrast, fast growing leguminous trees and bushes - if correctly identified and selected - can enhance soil fertility by bringing up nutrients from lower soil layers, litter fall and nitrogen fixation. Improved fallows are one of the many promising agroforestry technologies. Drawbacks include identifying sources of seeds or planting material, land pressures and separate traditional land and tree tenure right systems.

Windbreaks / shelterbelts are barriers of trees and shrubs that protect against damaging wind. They are used to reduce wind velocity, protect growing plants (crops and forage), improve micro-environments to enhance plant growth, delineate field boundaries, and increase carbon storage.

Suitability

Climate: AF systems can be found in all kind of environments. Systems with low tree densities are more suitable in low rainfall areas and high density systems in high rainfall areas, or where supplemental irrigation is available. In its diversity AF systems are suitable for a wide range of climates and agro-ecological zones. Parklands are not confined to specific agro-ecological zones and occur in various latitudes, but primarily in the semi-arid and subhumid zones of West Africa and in some parts of East

Africa. Multistory systems are more applicable in subhumid to humid environments or under irrigated systems, due to water requirements. Alley cropping and improved fallow have a wide range of applicability from semi-arid to humid.

Terrain and landscape: Suitable for all landforms and slopes: plains/plateaus as well as slopes and valley bottoms. AF is viable on steep land which otherwise is too steep for cropping: here AF can help building up terraces if trees are planted along the terrace risers.

Soils: Limitations are specie specific. In general, however, AF is suitable for a wide range of soils. AF system can restore the soil fertility, where other land use systems have mined (depleted) soil nutrients.

Resilience to CC: AF is tolerant to climate variability based upon the tolerances of the perennial species. AF systems are capable of creating their own micro-climates, and buffering extremes (heavy rainfall, dry and hot periods). AF is recognized as a greenhouse gas mitigation strategy through its ability to sequester carbon biologically. The adaptation and mitigation potential depends on the AF system applied.

Sources

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Liniger, H.P., Mekdaschi Studer, R., Hauert, C., & Gurtner, M. (2011). Sustainable Land Management in Practice – Guidelines and Best Practices for Sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO): Rome.

4.3 CONSERVATION AGRICULTURE

Conservation agriculture (CA), a variation of no-till farming, was developed in the 1980s and began to spread in sub-Saharan Africa through projects initially targeting large-scale farmers. It has since spread into small-holder systems in Southern and Eastern Africa, and more recently is being introduced into West Africa.

CA is a farming system that conserves, improves, and makes more efficient use of natural resources through integrated management of soil, water and biological resources. The three fundamental principles behind CA are: minimum soil disturbance, permanent soil cover (through crop residue management), and crop rotation. Each of the principles can serve as an entry point for introducing the technology; however, only the simultaneous application of all three results in full benefits.

Principles

Minimal soil disturbance: The main principle of conservation agriculture is minimal soil disturbance through the establishment of planting pocket, or channels, similar to the *Zai* hole technique. Planting pockets can be established by hand, animal traction or tractors fitted with a specialized implement. Pockets are maintained from one season to the next. Combined with crop residue management, the absence of cultivation allows that build-up of soil organic matter (less exposure to oxygen and thus less soil organic matter mineralization). Compared to conventional tillage, CA increases the organic matter content of soils, increasing their porosity and hence improving their ability to absorb and retain water – and this has two positive effects: first, there is more water to support crop growth and the biological activity that is so important for productivity, and second, less water accumulates and thus doesn't flow across the surface, causing floods and erosion.

Seeding is done directly into the planting pockets or channels. Prior sub-soiling may be required to break-up existing hard pans resulting from years of ploughing or hoeing to a constant depth.

Permanent soil cover is achieved by maintaining crop residues in-between the rows of planting pockets. Establishment of a permanent cover has multiple positive effects: increased availability of organic matter for improving topsoil, protection from raindrop splash, reduced soil crusting and surface evaporation, better micro-climate for plant germination and growth, reduced runoff and soil erosion, and suppression of weeds. In the initial years of using CA, weed pressure may require management through use of herbicides or hand weeding to reduce the seed bank. This declines after a few years, as the number of seeds in the seed bank is reduced and their growth is hindered by mulch cover.

Crop rotation: In order to reduce the risk of pests, diseases and weed infestation a system of rotational cropping is beneficial. Typical systems of rotation are cereals followed by legumes and cover/fodder crops.

Suitability

Climate: CA is suitable for all climates, although its specific benefits become more pronounced in less favorable climates, such as semi-arid zones, especially where low or uneven rainfall limits crop production. The technology has specific challenges in arid climates, however, it still performs better than tillage-based alternatives, given adequate mulch. The competition for crop residue in the dominant livestock-cropping systems in the Sahelian zone is a challenge.

Terrain and landscape: Suitable for flat to moderate slopes. Mechanized systems are unsuitable for slopes steeper than 16percent, but hand planting is possible on steeper slopes. Due to the reduced runoff and erosion it is particularly suitable for hillside slopes (under manual or animal traction).

Soils: Suitable for sandy loams to clay loams, but unsuitable for compacted hard soils or those at risk of waterlogging (poorly drained) and/or shallow soils. Compaction due to historical tillage practices can be dealt with through sub-soiling.

Sources

- Jat, R. A., Wani, S. P., & Sahrawat, K. L. (2012). Conservation agriculture in the semi-arid tropics: prospects and problems. *Advances in Agronomy*, 117: 191-273.
- Liniger, H.P., Mekdaschi Studer, R., Hauert, C., & Gurtner, M. (2011). Sustainable Land Management in Practice – Guidelines and Best Practices for Sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO): Rome.

4.4 MANURE AND COMPOSTING

Two primary methods for obtaining organic matter for field applications are the production of compost and the use of livestock manure. Manure can be collected from improved livestock pens or sheds where livestock are kept on litter or bedding, or can be deposited *in situ* through the pasturing of animals to graze on crop stubble and residues. The creation of compost involves the use of various techniques to speed the natural decomposition of organic matter. Compost can be made year round, depending on source and availability of material. Biodegradable matter (crop residues, collected plant biomass, household and kitchen wastes) is collected and composted directly or mixed with animal waste for rapid decomposition. Compost can be enriched with ash and/or natural phosphate to enrich its mineral content.

To make compost, biodegradable matter is typically placed in a pit. In the dry season, it is regularly sprinkled with water until decomposition is complete. Periodic turning of compost piles are required to speed and aid complete breakdown of material. Mature compost is then spread evenly over the land before sowing. The recommended amount varies depending on the type of soil: 6 t/ha every third year (heavy clayey soils), 3t/ha every two years (sandy-clayey soils) or 2t/ha every year (light soils). It is useful to calculate the total volume of compost required if all farmers adopt the practice and compare this to the available biomass of an area (and projected under CC).

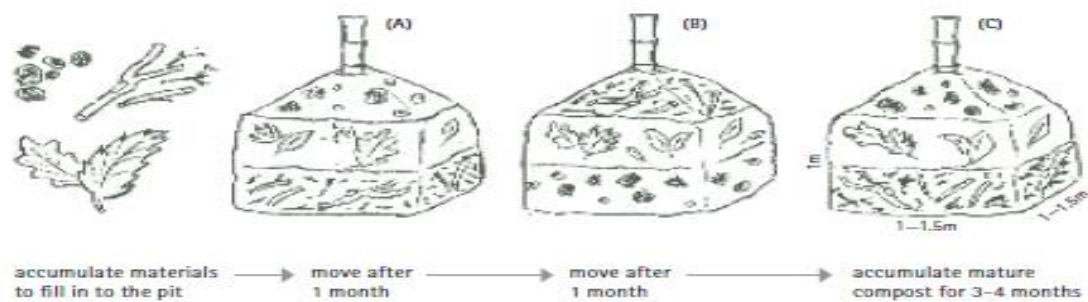
Unlike compost, manure collected from improved pens or livestock sheds is not completely decomposed, and the decomposition process can continue over several years. The use of manure on farmland entails some risks and disadvantages. As the manure is only partially decomposed – decomposition starts after the first rains begin – crops do not have access to sufficient nitrogen for optimal development. The use of partially decomposed manure also exposes plants to risk of being scorched if in close physical proximity. In spite of these drawbacks, the direct application of manure is commonly used by farmers as it requires less work than compost.

Compost Pit technical details

1. The pit should be less than 1 meter deep (pits should not be deeper than 1 meter). 1–1.5 meters wide and 1–1.5 meters long (or longer).
2. Some recommendations call for three layers of material in the pit:
 - a. Layer 1: A layer of dry plant materials, or mixture of dry plant materials with compost making aids like good soil, manure and/or some ashes. The layer should be 20–25 cm thick, i.e. about the depth of a hand at the sides. The compost making aids can be mixed with the water to make slurry. Water or slurry should be scattered by hand or sprinkled with a watering can evenly over this layer. The layer should be moist but not soaked.
 - b. Layer 2: A layer of moist (green) plant materials, either fresh or wilted, e.g. weeds or grass, plants from clearing a pathway, stems and leaves left over from harvesting vegetables, damaged fruits and vegetables. Leafy branches from woody plants can also be used as long as the materials are chopped up. The layer should be 20–25 cm thick at the sides. Water should NOT be sprinkled or scattered over this layer.
 - c. Layer 3: A layer of animal manure collected fresh or dried. The animal manure can be mixed with soil, old compost and some ashes (to accelerate decomposition) to make a layer 5–10 cm thick. If there is only a small quantity of animal manure, it is best to make a slurry by mixing the dung in water, and then spread it as a thin layer 1–2 cm thick.

3. One or more ventilation and/or testing sticks are kept vertically in the compost pit. Ventilation and testing sticks are used to check if the decomposition process is going well, or not.
4. After 3-4 months in warmer climate mature compost is created.

FIGURE 16. FILLING PITS A, B, AND C, WITH COMPOST MATERIAL, IN SEQUENCE



Source: Edwards, S., & Hailu, A. (2011)

Suitability

Degraded land low in organic matter and low fertility.

Areas with significant number of cattle, as cattle dung is useful in making compost.

Areas, where run-off is controlled so that the compost/manure added to the soil is not lost.

Sources

Edwards, S., & Hailu, S. (2011). "Climate Change and Food Systems Resilience in Sub-Saharan Africa." How To Make and Use Compost. FAO: Rome.

GIZ (2012). Good Practices in Soil and Water Conservation, A contribution to adaptation and farmers' resilience towards climate change in the Sahel.

Ouédraogo, E., Mando, A., & Zombré, N. P. (2001). Use of compost to improve soil properties and crop productivity under low input agricultural system in West Africa. *Agriculture, ecosystems & environment* 84(3): 259-266.

4.5 MULCHING

Mulching, the application of any organic material to the soil surface, reduces water loss, suppresses weeds, reduces raindrop splash effect, reduces soil temperatures and generally improves crop productivity through the gradual addition of soil nutrients. Traditionally mulching has been considered a technique to reduce evapotranspiration, but now it is used for the wide array of benefits pertaining to soil cover conservation and reduced runoff etc.

Mulching in Sahel usually involves leaving millet and sorghum stalks in the field after harvest. In cases where a relay crop has been planted, such as watermelon, the stalks serve to reduce the evaporation of remaining moisture from the soil and act as a barrier to prevent wind erosion, helping to trap the thin rich dust carried by the *harmattan* wind. Through the action of termites, the stalks and branches are broken down and gradually decompose becoming incorporated into the soil profile, providing nutrients and improving the soil structure. When accumulated in a single location and combined with a temporary coral the stalks serve as feed and bedding for livestock, and are effective for restoring infertile patches of cropland. The use of mulching can be combined with any other erosion control technique, such as contour stone bunds and grass strips, and is a central component of conservation agriculture.

Technical details

1. Mulching could be of two types:
 - a. *In situ* mulching systems - plant residues remain where they fall on the ground;
 - b. Cut-and-carry mulching systems - plant residues are brought from elsewhere and used as mulch.
2. The recommended amount per hectare is around 2 tons per hectare per year, which means 2 or 3 stalks per m².

Suitability

Degraded land

Windy region

Dry and hot areas

Sources

Bot, A., & Benites, J. (2005). The importance of soil organic matter: key to drought-resistant soil and sustained food and production (Vol. 80). FAO.

Lamers, J., Bruentrup, M., & Buerkert, A. (1998). The profitability of traditional and innovative mulching techniques using millet crop residues in the West African Sahel. *Agriculture, ecosystems & environment*, 67(1): 23-35.

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IMAGE 11. MULCHING WITH MILLET STALKS



Photo: GIZ, 2012

4.6 FERTILIZER MICRO-DOSING

To address the problem of soil fertility, scientists at ICRISAT have developed a precision-farming technique called 'Microdosing.' It comprises application of small quantities of chemical fertilizer with the seed at planting, or following 3-4 weeks after. The microdosing technique replicates what occurs in fields under zai holes, or conservation agriculture, where small amounts of fertilizer are applied in the planting pits, but does so at the field level without any physical alterations to the field.

The microdose technique uses about one-tenth of the fertilizer typically used on wheat, and one-twentieth of the amount used on maize in the USA. Yet in African soils crops are so starved of nutrients, such as phosphorous, potassium and nitrogen, that even micro applications, if appropriately timed, can double crop yields. By correcting soil deficiencies for essential nutrients with tiny doses, root systems are able to fully develop and capture more water, thereby increasing yields.

Farmers in ICRISAT's project countries have developed innovative techniques to apply microdoses of the appropriate fertilizer. While farmers in southern Africa use fertilizer measured out in an empty soft drink or beer bottle cap, farmers in West Africa measure fertilizer with a three-finger pinch and apply it in the same hole in which seed is sown. To date some 25,000 smallholder farmers in Mali, Burkina Faso, and Niger have learned the technique and experienced increases in sorghum and millet yields of 44 to 120%, along with an increase in their family incomes of 50 to 130%.

Technical details

1. Microdosing involves the application of small, affordable quantities of fertilizer with the seed at planting time, or as top dressing 3 to 4 weeks after emergence, instead of spreading fertilizer over the field.
2. Farmers who use microdosing apply 6 gram doses of fertilizer—about a full bottle cap or a three-finger pinch -- in the hole where the seed is placed (at the time of planting). That translates to about 67 pounds of fertilizer per hectare.
3. Where soil has formed a surface crust, farmers can use the zai hole technique, digging small holes before the rain starts, then fill it with manure, if available. When rains begin, they put fertilizer and seeds in the hole and the soil provides a moist environment, encouraging root growth, and the water is captured instead of running off the hard-crust soil.

IMAGE 12. MICRODOSE OF FERTILIZER BEING APPLIED TO CROP.



Photo: ICRISAT

Suitability

1. Suitable for degraded agricultural land, low in soil nutrients such as phosphorous, potassium and nitrogen.
2. The technique is suitable at all land forms in every climactic zone. The efficacy is enhanced if farmers control rainfall run-off from field receiving microdose applications.

Sources

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<http://www.icrisat.org/impacts/impact-stories/icrisat-is-fertilizer-microdosing.pdf>
- Hayashi, K., Abdoulaye, T., Gerard, B., & Bationo, A. (2008). Evaluation of application timing in fertilizer micro-dosing technology on millet production in Niger, West Africa. *Nutrient Cycling in Agroecosystems*, 80(3): 257-265.

4.7 INTEGRATED SOIL FERTILITY MANAGEMENT

Integrated Soil Fertility Management (ISFM) is a comprehensive soil management approach involving a combination of different methods of soil fertility amendment together with soil and water conservation. The approach considers the entire farm resource base and is organized around 3 principles: (1) maximizing the use of organic sources of fertilizer; (2) minimizing the loss of nutrients; (3) judiciously using inorganic fertilizer according to needs and economic availability.

In Sub-Saharan Africa, soil fertility depletion is reaching a critical level. ISFM techniques can regenerate degraded soils and then maintain soil fertility by using available nutrient resources in an efficient and sustainable way. ISFM uses of techniques that involve little cash expenditure by the farmer, such as organic fertilizers, crop residues and nitrogen-fixing crops, in combination with seed priming and water harvesting. The use of inorganic fertilizer, while requiring financial outlay, when combined with micro-dose application techniques minimizes expenses.

Technical details

1. For optimized soil fertility management an ISFM includes both organic and inorganic inputs:
2. Organic inputs:
 - a. *Manuring and composting* encompasses nutrient sources derived from plant or animal origin. Very often the availability of material is the main restriction, since it competes with animal feed/cooking fuel. The application of crop residues for mulching can also enhance soil fertility.
 - b. Use of seed priming can be used to reduce germination time. It ensures a more uniform plant establishment, and increases resistance to insects and fungus.
 - c. *Integration of nitrogen fixing crops*: Green manures, leguminous plants that are *intercropped* or planted in *rotation* with other crops or nitrogen fixing cover crops can aid soil fertility. Very often green manure is incorporated into the soil, which is not the most effective way, due to the fast decomposition and release of nutrients: it is often better to slash and directly drill into the residue. The natural incorporation of cover crop and weed residues from the soil surface to deeper layers by soil micro- and macro-fauna allow nutrients to be released slowly and can provide the crop with nutrients over a longer period. Additionally, the soil is covered by the residues, protecting it against the impact of rainfall runoff, wind, and high surface temperatures.
3. Inorganic fertilizer
 - a. Crop yields can be dramatically improved through the application of inorganic fertilizers at planting or as a top dressing after crop emergence. However, the application must be well targeted to reduce costs, to minimize GHG emissions and to avoid unhealthy plant growth, as well as accelerated decomposition of soil organic matter. Because soil fertility is the factor limiting production across much of the Sahel, small and targeted doses of fertilizer can increase production significantly. To achieve long-term soil fertility, however, micro-dosing should be combined with compost or manure because the small amounts of inorganic fertilizer used in micro-dosing are not sufficient to stop nutrient mining, nor do they directly build up the soil organic matter.
 - b. *Rock phosphate* has been promoted in West Africa for over 50 years, yet remains underutilized due to costs, limited availability in local markets, and the limited experience of farmers with applying it among other factors. A key issue is that the beneficial effects of rock phosphate application are spread over the course of several years. This can be a disincentive in contexts

where farmers have insecure land tenure rights and use traditional practices of rotating field management.

Suitability

ISFM is used mainly on annual cropland and mixed crop-livestock farming systems, unsuitable for rangeland.

Compost production is most effective in subhumid to humid areas where water and sufficient biomass is available. In drier zones pits are used to conserve moisture

Terrain and landscape: flat to hilly (transport is a heavy burden on very steep slopes)

Soils: ISFM is suitable for all types of soils, however it is difficult to increase the organic matter content of soils that are well aerated, such as coarse sands, and soils in warm-hot and arid regions due to the rapid decomposition of added material.

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5.0 TEMPERATURE AND WINDSPEED ABATEMENT

5.1 SAND DUNE STABILIZATION

Stabilization of active sand dunes is achieved through a combination of mechanical measures including palisades, and biological measures such as live fences and sowing of grass. These measures seek to stop sand encroachment and stabilize sand dunes on-site in order to protect villages, cultivated land, roads, waterways and other infrastructure. In addition to moderating temperatures and mitigating the impact of winds, benefits of dune stabilization include increased soil cover,

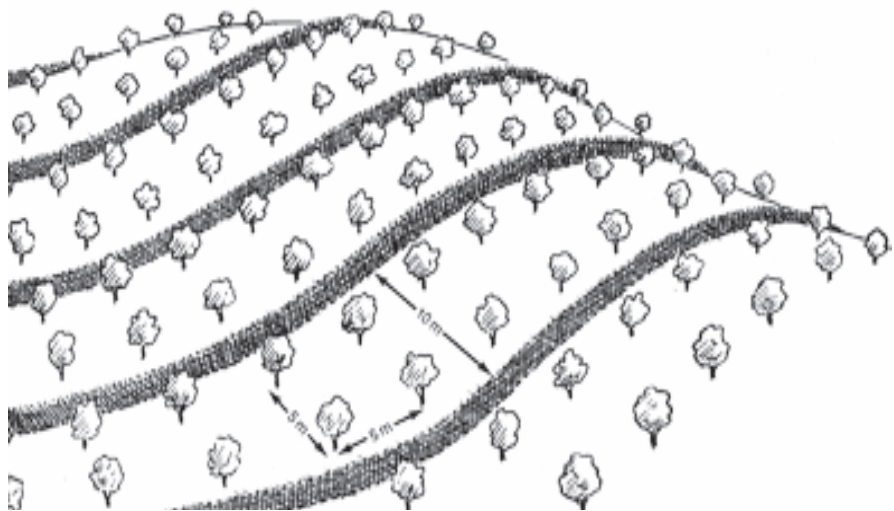
increased biomass/above ground carbon sequestration and storage, increased animal carrying capacity and increased soil fertility leading to more production of wood and fodder. The technology is currently applied on very large-scales within the Niger River basin.

The increasing speed at which desertification is progressing in Sahelian countries makes this technology one of the main instruments for combating the impacts of climate change. Land that has been sown with grass needs to be enclosed in the early years for protection from grazing animals in order to become established. The establishment of these systems requires high labor inputs that make them unattractive to farmers in Sahel outside of donor financed projects.

Technical details

1. Palisades used to stabilize dunes are made either of millet stalks, doum, or date palm fronds, according to local availability. Grass seeds are broadcasted.
2. Palisades are established perpendicular to the prevailing winds, at a spacing of 10 – 20 meters between rows depending on severity of sand encroachment and level of land degradation. The closer the spacing, the more effective is the protection.

FIGURE 17. LAYOUT OF PALISADES AND TREE PLANTING FOR SAND DUNE STABILIZATION.



Source: Liniger, H.P., et al. (2011)

3. Tree seedlings or cuttings are planted on a 5 m x 5 m grid, with a density of 400 trees per hectare. *Euphorbia balsamifera*, *Prosopis chilensis*, *Ziziphus mauritiana*, *Acacia senegal*, and *Bauhinia rufescens* are some of the species commonly used.

Suitability

Climate: semi-arid

Average annual rainfall: 250-500 mm

Soil parameters: good drainage; low soil organic matter

Slope: high dunes with steep slopes (> 20%)

Landform: mainly dunes

Altitude: 0-100 m a.s.l.

Sources

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5.2 FIREBREAK

Firebreaks are a precautionary measure designed to protect forage on rangelands during the dry season. Firebreaks cut vast tracts of rangeland into smaller areas, with a view to limiting damage in the event of wildfire. They can also be established along traditional livestock herding routes. The gap in the vegetation makes it easier to put fires out along the corridor, which facilitates rapid access. When the fire reaches the firebreak, there is no combustible material to fuel it and it burns itself out

IMAGE 13. FIREBREAK SLOWING THE SPREAD OF WILDFIRE.



Source: <http://rangeforestry.com/services>

The use of firebreaks is particularly important as a precautionary measure in years when rainfall is high and there has been robust vegetative growth. Due to the low standing fuel load in the Sahel, bushfires only pose a threat in the dry season following a good rainy season when grass growth is good. In contexts where there is high year-to-year variability of rainfall levels, the construction of firebreaks as a precautionary measure that should be used after a rainy season with abundant rainfall.

Technical details

1. Firebreaks can be made manually or by machines, in either case a 10m-15 m corridor is cleared perpendicular to the prevailing wind direction after the rainy season.
2. The corridor is cleared of all herbaceous vegetation manually, using tools such as rakes, shovels and axes, or mechanically using a tractor pulling a large harrow, a four-wheel-drive vehicle pulling the blades behind it or graders. Trees are pruned, but left in place.
3. Firebreaks must be regularly maintained after they have been created. No new plants should come up in the firebreak, because if vegetation grows back into the break, the purpose of firebreak is defeated.

Suitability

This technique is useful on rangeland with rainfall between 150 and 300 mm.

Any area with good vegetation is prone to wildfire as they are frequent on good-quality rangeland with over 1t/ha of biomass. Thus firebreaks are suitable for any area that has good vegetation which dries in summer.

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